Vol. XXXVIII. *February, 1920.* *No. 2.*

BIOLOGICAL BULLETIN

NOTES ON THE BIOLOGY OF SOME COMMON LAMPYRIDÆ.[1]

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CONTENTS.

INTRODUCTION.

The fireflies (family Lampyridæ) are among the most common of insects, yet because of the larval habits of most species, comparatively little is known regarding them except what has been learned from a study of the adults. The larval forms are rarely seen, as most of them are active only at night, and usually are found on, or in the ground, in damp or marshy regions.

The insects were observed both in the field and in specially prepared large plant-pots at the insectary. These pots were filled about half full of rich mellow earth on which was placed a small amount of moss. Some of the pots were covered with glass, while others were covered with cheese cloth. Since oviposition occurred very readily in captivity, eggs were obtained for a study of the incubation periods of the different species, by confining ripe females in small jars that had been partially filled with earth. For a study of the feeding habits of the larvæ and adults, these insects were confined in glass jars, some of which

[1] Contribution from the Entomological Laboratory of Cornell University.

contained only a small amount of moist filter paper, while others contained earth and moss. Since no reference was found to a published account of the nature of the mouth-parts of any of our native firefly larvæ, these structures were figured in order to better illustrate the method of feeding of these larvæ.

The following species were studied: *Photinus consanguineus* Lec., *Photinus scintillans* Say, *Photurus pennsylvanica* DeGeer and *Pyropyga fenestralis* Mels.

The author is indebted to Dr. James G. Needham, Dr. William A. Riley and Dr. O. A. Johannson, under whose supervision the greater part of this study was made, for their helpful suggestions and criticisms.

History of Biological Work on Lampyrids.

Although many workers, both in this country and in Europe, have studied the light-organs of the fireflies, comparatively little has been done on the biology of this group of insects.

Newport (1857) studied the life-history of the glow-worm, or larva, of *Lampyris noctiluca*. He not only discussed the development and general habits of these larvæ, but he also performed several experiments to determine the nature of their feeding habits.

Hudson (1891) published an interesting account of the habits and life-history of the New Zealand glow-worm.

Barber (1905, 1914) described the egg-laying habits of Phengodes, together with certain habits of this group of fireflies.

Bongardt (1904) published a brief account of the biology of certain European Lampyridæ.

Knab (1905) described the habitat, flight and light-emission of *Photinus scintillans* and *Photurus pennsylvanica*.

McDermott (1910, 1911, 1912, 1914) studied especially the nature of the flashing of fireflies, together with the attraction of the sexes by means of light-emissions.

Olivier (1911) described the distinguishing structural characters of the common species of fireflies. In addition, he discussed their general habitats and distribution.

Mast (1912) studied the sexual attraction of fireflies (*Photinus pyralis ?*) with special reference to their orientation. He found

that the female, in responding to the flash of the opposite sex, always turned the ventral side of her abdomen, so that it would emit light in the direction of the male.

Fabre (1913) maintained that the glow-worm, in feeding on snails, injected a substance in the nature of an anæsthetic which paralyzed its host.

Vogel (1915) did by far the best biological work that has been done on this group of insects. He described the external and internal anatomy of the larva of *Lampyris noctiluca*, together with its life-history. He observed that the larva lived in the ground, and that it fed on snails. By making a careful study of the structure of the mouth-parts, pharynx and gizzard he found that the digestive juices of the mid-intestine were emitted through the hollow mandibles. By this means the larva was able to paralyze its prey, and to digest the tissues before eating them.

Haddon (1915) described also the process of feeding and the nature of the mouth-parts of *Lampyris noctiluca*.

Blair (1915) and *Morse* (1916) reported the interesting phenomenon of the synchronous flashing of fireflies, in which the fireflies in a given locality were found, at times, to flash in unison.

Williams (1917) described the life-history of several of our common Lampyrids. His discussions of the biology of *Photinus consanguineus* and *Photurus pennsylvanica* are especially valuable.

Photinus consanguineus Lec.

The insects of this species are elongate and slender with the head covered by the prothorax. The prothorax is rounded on the anterior and lateral sides, truncate behind with the angles acute. It is light yellow with a black median bar, which is bordered with pink on either side. The elytra have wide side margins and bear two or three sub-obsolete carinæ. The suture and side margins are pale yellow, while the remainder of the elytra is grayish in color. They are granulate and rather pilose. The abdomen in the male is depressed, but in the female it is often rounded, due to being distended with eggs. The eyes of the male are larger and better developed than those of the female. The light-organs of the male cover the entire sternites of the sixth and seventh abdominal segments, while in the

female the organ occupies only a small area on the sixth abdominal segment. They measure from 8 to 12.5 mm.

LeConte reports them from Massachusetts, Pennsylvania and Virginia. Blatchley lists them for Indiana, and Williams found them abundant in Massachusetts.

The biology of this species has been well described by Williams (1917), so an attempt will be made here to discuss only a few of the more important features.

The adults begin to emerge about June 1 and can be found along moist areas until about the first of August. They are frequently found in association with *Photinus scintillans* and *Photurus pennsylvanica*. The males are active fliers, and though the females have well developed wings they were never found in flight. The flight of the males begins about 8:15 P.M. and continues until about 10:00 P.M. (old time). The light of the male is a single bright flash, though at times he emits two or three flashes in rather close succession, but in every case there is a considerable interval between each flash. The female of this species crawls up a stem of grass, or some similar object, and emits a faint flash in response to the flash of the male. Just before emitting the light, however, she turns her abdomen so that the ventral side is in the direction of the male, thus in part, at least, obviating the necessity for larger light-organs.

What was discribed as the synchronous flashing of fireflies was first discussed by Blair (1915), who reported observing fireflies, in a certain locality, flashing in unison. Later his observations were confirmed by other writers. Morse (1916) reported an observation in which the light emitted by these little creatures pulsated in a regular synchronous rhythm, so that at one moment the tree, about which they were flying, would be one blaze of light, while at another the light was dim and uncertain.

According to Blair (1915) and McDermott (1916), this phenomenon does not occur among the American species of *Photinus* and *Photurus*. The writer, however, observed the flashing of fireflies in unison on two very dark evenings during the present summer while collecting eggs and larvæ at Ithaca, New York. Toward the south side of the City Cemetery is a small valley,

and on both occasions the entire valley, for a moment, was a blaze of flashing lights, and then for a moment it was in darkness, except for an occasional flash, which seemed to come from fireflies of different species than those that were flashing in unison. The fireflies in this particular locality were almost entirely of the species *Photinus consanguineus*, and at each period of flashing both males and females were observed to emit light. On both nights this phenomenon occurred shortly after it became dark, at approximately 9:00 P.M. On the first night the phenomenon was observed for approximately fifteen minutes. How much longer it continued after that was not determined. By very careful observation it was discovered that each period of flashing started on the crest of the hill at the south side of the valley, by one, or only a very few flashes, and that the impulse stimulated by these few insects instantly appeared to sweep over the valley, resulting in the great mass of flashing lights. On the second night an experiment was performed in which it was discovered that, by standing on the side of the valley and causing short flashes with a pocket flash-light, the fireflies of the entire valley responded. At first, after estimating the length of the latent period, the flash-light was flashed just before the normal time for the fireflies to flash, with the result that the entire mass of fireflies responded. Then two flashes were emitted from the pocket flash-light with the interval between flashes reduced to about three fourths that of the normal flashing period, and the fireflies responded with apparent equal results. Finally, the period was reduced to approximately one half the normal time. The fireflies as a mass appeared to respond to the first short flash. The second time a large per cent of them responded, but after this second short period, the flashing in unison was so disturbed that each insect flashed independently of the flashing period of the others. Blair (1915), in commenting on the reason for the synchronous flashing of fireflies, states: "The flashing in unison is too regular to be caused by chance puffs of wind. A more probable explanation of the phenomenon is that each flash exhausts the battery, as it were, and a period of recuperation is required before another flash can be emitted. It is then conceivable that the flash of a leader might act as a

stimulus to the discharge of their flashes by the other members of the group, and so bring about the flashing of the whole family." From the observations and experiments performed above, it seems evident that the theory of a leader is the most probable. Although the author has done extensive collecting of these insects during the past four summers, at no time was this phenomenon observed on the part of any of our other native species.

The small, smooth, spherical eggs are laid on the soil at the base of the roots of grass and moss where they hatch in about twenty to twenty-two days. The larvæ are slender, elongate, and of a rather uniform dark grayish color. They were found chiefly a short distance below the surface of the soil, though a few specimens were taken at the surface. It seems, however, that its habitat is subterranean, rather than terrestrial, in contrast to that of *Photurus pennsylvanica*. They are predacious, feeding on snails, etc., similar to the other species studied.

It seems very evident that the insects have a two-year life cycle, as both mature and half-grown larvæ were taken at the time of pupation.

Pupation takes place in the soil near the surface of the ground. Here the mature larvæ excavate a little chamber, in which the period of transformation is spent. After transforming to pupæ they lie on their backs in an arcuate position. In this condition they measure about seven mm., but when straightened out they are about nine mm. long. The pupæ are yellowish white in color with the pleural regions somewhat pinkish. The pupal period lasts from twelve to fifteen days.

Photinus scintillans Say.

The adult beetle of this species is rather elongate and slender, somewhat flattened with the head completely covered by the prothorax. The antennæ are eleven-segmented, the second segment being short and transverse. The prothorax is rounded anteriorly and along the sides, truncate behind with the angles acute. The elytra have wide side margins. The head is black. The prothorax is pale yellow, except the small black median bar on its central posterior half, which is bordered with pink. The elytra are pale yellow, except the side and suture margins which

are a lighter yellow. They are finely granulate and pubescent. The females resemble the males except that they are slightly larger and their abdomens, frequently distended with eggs, project considerably beyond the elytra. The eyes of the male are larger than those of the female. In the male the light-organs cover the entire sternites of the sixth and seventh abdominal

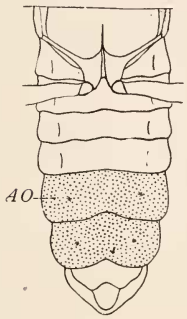

FIG. 1.

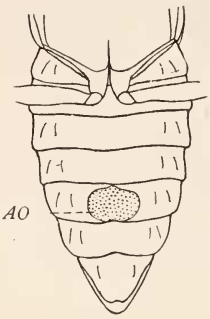

FIG. 2.

FIG. 1. *Photinus scintillans* male, ventral view of abdomen. The shaded portion on the sixth and seventh abdominal segments represents the adult light-organ (*AO*).

FIG. 2. *Photinus scintillans* female, ventral view of abdomen. The shaded area on the sixth abdominal segment represents the adult light-organ (*AO*).

segments, while in the female the organs occupy only a small area at the center of the sixth sternite (Fig. 1 and Fig. 2). The beetle measures from 5.5 to 8 mm.

These insects were found by LeConte in Massachusetts, Pennsylvania and Kansas. Blatchley found them in Indiana.

The natural habitat of this species appears to be very similar to that of *Photurus pennsylvanica*. Yet, however, they are much more widely distributed, and are often found in drier localities than is characteristic of this species. They are very common about central New York, being our most common firefly. They were found very abundant at Ithaca, New York in the City Cemetery on Stewart Avenue, and, in fact, on the campus, and on the lawns near many of the private houses.

The period of emergence for this species varies from about June 1 to July 20, depending on the season.

During the daytime the adults are rarely found, as they remain hidden underneath the leaves of low herbage, or near the ground covered by grass or moss.

Neither sex was observed feeding, so it is not known whether these insects eat as adults or not, but it is probable that they do since they live for two or three weeks.

The flight of these insects begins very early in the evening, considerably earlier than that of the other native luminous species. Almost with the first sign of twilight they are flying about, and because it is comparatively daylight the beetles themselves can be distinctly seen. In fact, when they begin flying, their flashes appear rather faint, due to the daylight obscuring their brilliancy. Before total darkness sets in, the flight of these insects has ceased, unless for an occasional one here and there. These few stragglers, however, soon stop. Among the fireflies there seems to be, to a certain extent, an evening periodosity of flight. This species of fireflies flies only during twilight, after which other species as *Photinus consanguineus* and *Photurus pennsylvanica* take its place. The flight begins shortly after 7:30 P.M. and continues until about 8:30 P.M.

In comparison with most of our luminous species of fireflies, the males of this species fly very low and slowly, and emit one distinct flash at each period of flashing. Females were never taken in flight and it seems probable that they never fly. Instead, they climb to near the top of some projecting blade of grass, or some similar object, and apparently remain quiet until a male comes near. Like the male, the female emits only one flash, but it is much less distinct.

There can be little doubt but that the light-emissions among these insects serve as definite signals between the sexes, by which means the male is able to find the female of his species. Numerous observations confirming this were made, which can be well illustrated by the following example: on the evening of June 30, 1916, a male *Photinus scintillans* was observed flying about two feet above the ground, and a second after he flashed a female that was almost underneath him flashed. He appeared to drop directly to the ground, but his velocity of flight carried

him about a foot beyond where she was resting. He at once quickly ascended the nearest stalk of grass, seemingly expecting to find her near its top. He then began to descend, at which time he emitted a flash of light and she responded. He then rushed up another stalk of grass that was in her direction and, not finding her, he flashed again. She responded, and he flew in her direction but alighted nearly a foot beyond her, and he then immediately ascended the nearest stalk of grass. Flashes were exchanged for a period of twelve minutes, during which time he ascended about twenty stalks of grass, and he flew in her direction five different times before he finally found her. Each time she responded to his flash, and each time she orientated her abdomen so that the light was emitted in his direction. It was 8:13 P.M. when he found her, and at once copulation took place. This lasted until 8:58 P.M. when they separated, and at once crawled down the blade of grass to the ground where they were concealed by the vegetation. On another occasion, while the male was in the grass about a foot from a female in his search to find her, a small pocket flash-light was used, in which it was found that she would readily respond to a very short flash. As soon as the pair was in copulation the flash-light was again flashed several times, at different intervals, but with no response. After the pair separated the flash-light was again flashed, but with no results. After copulation took place neither one of the pair was observed to flash, and after separating they concealed themselves in the grass, without emitting light, all of which seems still further to prove that the light-organs serve to bring the sexes together, and having accomplished this end, they are no longer functional until at some possible later date. In a very few instances flashing was observed on the part of one of the copulating members, but it seemed to occur only when they were disturbed, which was the exception rather than the rule.

The pocket flash-light referred to above was used with good success in collecting females. They usually responded when the light was at a distance of at least eight feet, but rarely responded when it was nearer.

Oviposition usually took place about one week after emergence

and continued for a period of two or three weeks. As the eggs of the females do not all ripen together, they are deposited over a considerable period of time. Like the other species studied the small, whitish eggs were deposited on the ground, at, or near, the base of moss and grass. They were usually laid singly, though in a few instances they were found in masses. When deposited they were covered with an adhesive substance, which caused them to adhere to the object on which they were placed. The period of incubation occupied from eighteen to twenty-one days.

In this species, as in all the others studied, the eggs appeared very slightly luminous at the time of laying, but this faint luminosity disappeared in about a day and there was no more light emitted from the eggs until the larval light-organs became functional shortly before hatching.

The newly hatched larva is whitish, except for the black lateral eyes and brownish mouthparts. It soon becomes pigmented, appearing dull gray in color. At this stage it measures about 2.4 mm.

The mature larva resembles in general shape that of the first instar. It is elongate and narrow, varying from 12 to 13 mm. in length. Its head is small, being about half as wide as the prothorax. Like the other species studied, the head can be withdrawn into the thorax. The body is widest in the region of the thorax and tapers gradually posteriorly. The head is black, the tergites dull gray, and the pleural regions slightly pinkish. The habitat of the larva is largely subterranean, though it is usually found near the surface. Its feeding habits resemble very closely those of *Photurus pennsylvanica*. It is not active during the day.

The larvæ were not reared from eggs to adults, yet while collecting these insects each spring, larvæ of two sizes were found: some that were mature and others that were about half as large, indicating that the insect, probably, has a two-year life cycle.

Pupation usually takes place near the surface, although it sometimes occurs under stones. The pupal period is rather brief, taking from nine to twelve days. The pupa assumes an arcuate position, lying on its back within the pupal cell. It

measures about 8 mm. in this arcuate position, but when straightened out it is about 10 mm. long. The lateral tergites project slightly and each bears a group of short setæ. The body is somewhat flattened, being yellowish white in color except along the lateral sides of the thorax and adbomen, which are slightly pink. The larval light-organs function throughout the pupal period and do not degenerate until shortly after the emergence of the adult. The adult light-organs, which develope independently of the larval organs, become functional shortly before the adults emerge.

Photurus pennsylvanica DeGeer.

This is one of the largest of our native fireflies throughout central New York, and though very common in certain moist localities, it is by no means our most common species.

The adult insect is elongate, somewhat flattened, with the head partially covered by the thorax. The head is rather rounded, and slightly narrowed behind the large convex eyes. The antennæ are eleven-segmented, slender and tapering, extending about half the length of the body. The prothorax is rounded anteriorly and along the sides, and subtruncate posteriorly. It is dull yellow with a central and basal dark stripe, while the disc at each side of the dark area is red. The surface is rather coarsely punctate. The elytra are elongate, extending considerably beyond the end of the abdomen. They are brownish except the lateral margins and a narrow tapering area extending from the anterior part to beyond the center, which is a dull yellow. The body is covered with short yellowish pile. The length ranges from 12 to 15 mm. An illustration of the male is shown on Fig. 3.

The sexes are similar in form except that the female is slightly larger than the male. The light-organs of the male cover the entire sternites of the sixth and seventh abdominal segments (Fig. 4), while these organs occupy only about two-thirds of the corresponding region in the female (Fig. 5). In the male the abdomen ends in a point while that of the female is truncate on the tip.

This insect is widely distributed throughout North America.

According to LeConte (1851) it is abundant in every part of the United States. Blatchley states that it is the most common firefly in Indiana. Williams also makes a similar statement for Massachusetts.

As is characteristic of our luminous fireflies, the adults of this

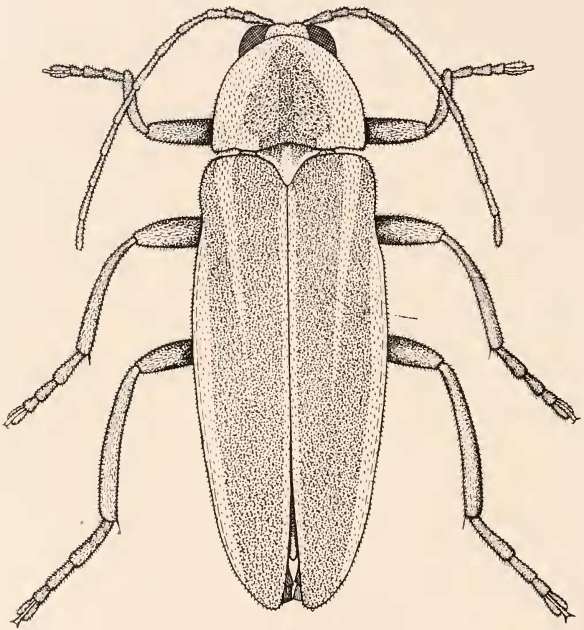

FIG. 3. *Photurus pennsylvanica* male.

insect are usually found active only at night. Like many other insects, this species has well-defined centers of distribution, being rarely found except along marshy or moist localities. This, however, is more characteristic of the larvæ, but as a rule the adults are found comparatively rarely outside of such regions. They were found most abundant in the City Cemetery, on Stewart Avenue, and in the Renwick marshes, at Ithaca, New York. The cemetery, while not in any sense marshy, has been filled in

with dark loamy soil, which is usually moist in the depressions along the walks and between the graves.

The period of emergence for this species, in this locality, extends from June 5 to July 15, depending on weather conditions.

During the daytime the adults remain in seclusion, usually at the base of moss or grass, although occasionally specimens were found clinging to the underside of leaves of low vegetation.

Many insects during their adult life eat little or no food, but the adults of this species, especially the females, are very vora-

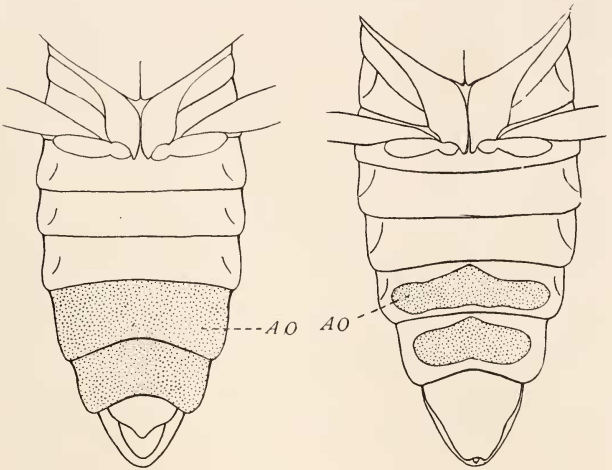

FIG. 4. FIG. 5.

FIG. 4. *Photurus pennsylvanica* male, ventral view of abdomen. The shaded portion on the sixth and seventh abdominal segments represents the adult light-organ (*AO*).

FIG. 5. *Photurus pennsylvanica* female, ventral view of abdomen. The shaded portion on the sixth and seventh abdominal segments represents the adult light-organ (*AO*).

cious in their feeding habits. During the evening, while they are active, they are either found flying, or on the ground, usually about the base of grass, actively in search of food. The females were commonly observed devouring other species of fireflies (*Photinus scintillans*, *Photinus marginellus* and *Photinus con-*

sanguineus). In each case, however, the firefly being devoured was a male, which had probably attracted the *Photurus* by means of its frequent flashing, as the females of these species flash very rarely, except in response to the flash of the male. In captivity the female was often found devouring the males of her own species, and occasionally a member of her own sex. The males were not found feeding, though it seems probable that they also are predatory at times.

Though both sexes fly readily, comparatively few females were found on the wing during the early part of the season, although later (about July first to fifteenth), when it seemed evident that there was a less abundance of males, the females were found flying fully as much as those of the opposite sex. The flight began about 8:15 P.M. and continued until after 10:00 P.M., although by that time comparatively few were flying. Some have been observed on the wing as late as 1:00 A.M. Unlike our other native species, these fireflies frequently fly high and their flashes can often be seen in the tops of the highest trees.

The flashing of this firefly is very distinctly different from that of any of our other native species. Like the other fireflies, these have definite periods of flashing. The male flashes three, four, and even five times in rapid succession at each period. The flashes are bright, although they become less distinct at the end of each period. In the case of the female the number of flashes at each period is reduced to three, two or one. There is usually a longer period between the flashes than in the male and they are less distinct. These periods of flashing occur at rather regular intervals of about eight to ten seconds. The male flashes slightly more frequently than the female. When on the ground the brilliancy and regularity of flashing, on the part of both sexes, seems to be the same as when they are flying.

It is agreed by most students of fireflies that the light-emissions serve to bring the two sexes together, although McDermott (1911) and Williams (1917) seem to doubt that they can serve such a function in this species. In the other native luminous species that were studied there is a definite interchange of flashes, in which the female responds to the flash of the male. In *Photurus* the female is an active flier and flashes frequently,

whether in the presence of the male or not. In no case was there observed a definite exchange of flashes between the sexes, yet it seems very evident that the light-emission functions in bringing the sexes together. On several occasions, while holding females in my hand, males flew to them and they would have alighted had my presence not scared them away, and on two occasions, while holding males, females flew and alighted beside the captured males. This would lead one to believe that there is a definite sexual attraction by means of light-emissions between the sexes of this species, and that the female, having become an active flier, is also attracted to the male. In each case observed where the two sexes were attracted to one another, both continued to flash actively, but in no case was there any evidence that one was responding to the flash of the other. In no case did the female of this species assume a vertical position or expose the abdomen so that the light would be flashed in the direction of the male. It is possible that the brilliancy of the light-emissions on the part of the female has obviated the necessity for such exposure. Even while the females were on the ground the flashes were easily perceptible for a considerable distance.

Copulation was observed in the field on three occasions. Unlike our other native fireflies, these beetles were never observed in copula on, or near, the ground, but while clinging to the leaves of trees, often at considerable height. While in this state the flashing of the light-organs apparently ceased, though one female was found emitting a rather dim continuous glow during this period.

Egg laying usually began about one week after emergence and continued at intervals for a period of about two or three weeks. Several females, which were captured early in the season, were dissected to determine their egg laying capacity. On the average, each female contained about fifty mature eggs, with from seventy-five to a hundred smaller ones, indicating that the eggs were at varying stages of maturity.

The characteristic place for the oviposition by the female is at the base of grass or moss in damp loamy soil. Oviposition was not observed in the field, yet on several occasions eggs were found which had been deposited at the base of the roots of grass

and moss. In confinement, at the insectary, oviposition was observed on several occasions. The female walked slowly over the soil, thrusting out her long ovipositor into the depressions in the earth, where the light yellowish eggs were deposited. Eggs laid by these females were usually deposited singly, though sometimes in masses. Some were placed from one eighth to a quarter of an inch underneath the surface, others on the surface, and some were deposited on the roots, basal stems and leaves of moss and grass. The egg (Fig. 6) is small, nearly spherical, about .7 by .8 mm. in diameter. It is without surface markings, though at the time of laying it is covered with an adhesive surface.

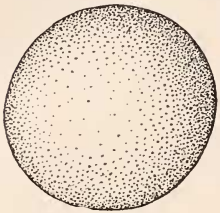

FIG. 6. *Photurus pennsylvanica* egg.

It is frequently stated in literature that the eggs of fireflies are luminous, and Williams (1917) states that the eggs of this species glow when deposited and probably continue to emit light until the time of hatching. The certainty of this statement seems in doubt. At the time of laying, the eggs were found to be very slightly luminescent for a period of two days, but in no case did they, at this period nor until the light-organs of the larva were developed, definitely emit light. Eggs removed from the ovaries of a ripe female showed no evidence of luminosity, though Williams thought he saw a light in some of the eggs that he so removed. Fabre (1913) states that the eggs are luminous even before leaving the body of the mother, but this seems very much in doubt. The so-called luminescence of the eggs at the time of laying is probably due to the substance with which they are covered, rather than to any internal property of their own, and as this becomes dry the slight luminescence disappears. At a period about four days before the eggs hatch the larval light-organs become functional, and from this time until hatching, the eggs emit a distinct light.

In the breeding cages at the insectary where normal outdoor conditions were maintained, the eggs of this species hatched in from twenty-five to twenty-seven days, depending on weather

conditions at different periods. The largest number hatched on the twenty-sixth day. The newly hatched larvæ are not pigmented for a period of a few hours, but they soon resemble the mature larva in shape and appearance, except for their minature size. At this stage they measure about 2.25 mm. in length. As nearly as could be determined the larvæ were in the fourth instar by winter. The first two molts take place rather early in the life of the larva, the first occurring at about the age of two or three weeks. The mature larva (Fig. 7) is elongate, rather narrow, varying from 16–19 mm. in length, and it is about three times as long as it is wide. The head is small, a little less than one third as wide as the prothorax, and it can be withdrawn into a pouch within the thorax. The antennæ are three-jointed, the mandibles are arcuate and notched near the middle. The legs are somewhat spinose and of nearly uniform length. The body is much flattened. The prothorax is rounded on the anterior and lateral sides and subtruncate behind, much the same as in the adult. This is the largest of the body segments. From the metathoracic segment to the caudal end of the larva the tergites are concave posteriorly especially the caudal ones. Each bears a spine on its caudo-lateral margin. The head, mouth-parts and tergites are colored a dark brown, except for a few irregular pale yellowish areas. The dorsal surface is more or less irregularly coarsely punctate. The last segment of the abdomen is provided with numerous retrac-

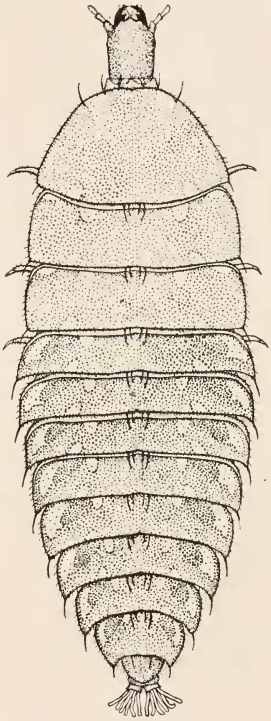

FIG. 7. *Photurus pennsylvanica* larva, full grown, dorsal view.

tile elements, the caudal filaments (Fig. 8, *C*, *F*), which are used in propelling the body forward. On the lateral sides of the eighth abdominal sternite are two luminous areas, the larval light-organs (*LO*).

Resembling to a certain extent the habits of the adults, these larvæ unless disturbed were not found active during the daytime. At this time they are usually underneath stones or concealed in depressions in the ground. At night they become active and their light can be frequently seen as they wander about in their natural habitat. When the ground is smooth a small garden rake is of advantage in collecting them, as they can be easily disturbed by it, thus exposing their light-organs to view. The glow of their light-organs is not visible when the larvæ are lying on the ground, as it can only be seen when the ventral sides of their abdomens are exposed to view. A flash-light is also of assistance in collecting them.

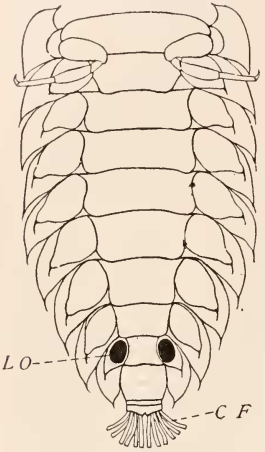

FIG. 8. *Photurus pennsylvanica* larva, ventral view of abdomen. *LO*, larval light-organ; *CF*, caudal filaments.

While in the field, collecting on numerous occasions during the evening, larvæ were found wandering about apparently in search of food. On two occasions they were taken while feeding on snails, which they had evidently killed a short time before being discovered. As the larvæ crawled about, their heads were fully distended, the maxillary palpi and antennæ were constantly in motion, and it appeared as if they were feeling their way by means of these organs. From observations on their movements, even when a snail was very near, it seemed very probable that the larvæ find their food by chance, and having found it they tap it several times with their maxillary palpi and antennæ before beginning to feed. Since newly hatched larvæ and those one-year-old were abundant, efforts were made to determine more in detail the methods of feeding and the nature of their food.

Larvæ taken into the laboratory were placed under as normal conditions as possible, where various experiments were performed to determine the possible nature of their food. In no case were newly hatched larvæ found in the act of killing their prey, though they were observed feeding on bits of snail that was cut up and placed near them. They fed much the same as the older larvæ, and, in fact, there can be little doubt but that their food habits are similar. As the larvæ were not active during the daytime, and as they were disturbed by artificial light, my observations on the feeding habits were largely limited to the larvæ of *Pryopyga fenestralis* which is active during the day. On six different occasions a slug (*Agriolimax campestris* Binney) was placed with six larvæ of *Photurus pennsylvanica* and in every case it had been eaten before morning. A slug (*Agriolimax agrestris* L.) and a snail (*Succinea avery* Say) were put in with six larvæ. The snail was eaten during the first night, but the slug was not killed and eaten until the third night. On two occasions a small earthworm (*Lumbricus terrestris* L.) was placed in a jar, without earth, which contained eight larvæ. One was killed and eaten the second night, and the other on the fifth night. On two occasions a very large specimen of *Limbricus terrestris* was placed with twelve larvæ. In each case the earthworm was not disturbed, though it remained with the firefly larvæ for over a week, and they received no other food during that time. On two occasions a potato-beetle larva (*Leptinotarsa decemlineata* Say) was placed in a jar with six larvæ and each time it was eaten the first night. On two occasions cutworm larvæ (*Paragrotis messoria* Harris, *Paragrotis tessellata* Harris and *Peridroma margaritosa* Haworth) were each placed in jars with six larvæ and in every instance they were eaten the first night. Finally, on four different nights, two second and two third stage squash-bug nymphs (*Anasa tristis* DeGeer) were placed with six larvæ, and in each instance they were eaten before morning. Sowbugs (*Oniscus asellus* Paulmeier), wireworm larvæ (*Agriotes mancus* Say), ants (*Formica* sp.) and coleopterous beetles including the common ground beetles (*Nebia pallipes* Say and *Chælnius pennsylvanicus* Say) were placed in with these larvæ, but they were never eaten, indicating that the

larvæ require a soft-bodied animal into which they can pierce their mandibles and inject the poisonous secretion.

These results, while giving no definite data as to the exact food of these larvæ, lead one to conclude that they probably eat any soft-bodied insect larva, mollusca or annelid, that they happen to find in their nocturnal wanderings. Snails are probably one of their chief foods, and though these animals are not supposed to be very abundant, they were found abundantly at night in the damp regions where these larvæ live. Cutworm larvæ were also abundant. Earthworms, except very small ones, were not eaten until they had been with the larvæ for a considerable length of time, while other food was eaten very readily. This would seem to indicate that probably snails and small insect larvæ, expecially cutworms, are their natural foods.

Among the larvæ of many members of the Lampyridæ, as well as among certain other more or less widely separated groups of insects, digestion takes place entirely, or partially, outside of the body. This is accomplished by the digestive juices being exuded from the mouth upon the food which is later eaten by the larvæ in a more or less completely digested condition.

It is characteristic of most insects that feed in this way to have

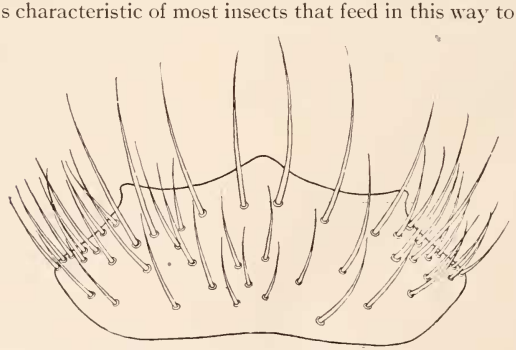

FIG. 9. *Photurus pennsylvanica* larva, labrum, dorsal view.

very small heads, so that the mouth is not sufficiently large to take in only very small pieces of food. These insects, like the larvæ of the Dytiscidæ, are predaceous, feeding on living animal food. The nature of this food is such that it could not be easily

chewed, like vegetable food or decayed animal tissues, and hence it seems that some such method of feeding became necessary. Some have the mandibles grooved, as the larvæ of the Chrysopidæ and Myrmeleonidæ, while others have them pierced by a small canal, such as certain of the larvæ of the Dytiscidæ and Lampyridæ.

The most extensive work on this subject was done by two European workers, Vogel (1912, 1915) and Haddon (1915), although earlier workers made a less detailed study of the problem.

When the head of this insect is withdrawn into the thorax, only the tips of the mandibles and other mouth-parts are visible, but when it is extended the large mandibles surrounded by the other mouth-parts can be distinctly seen.

As the anterior half of the mandibles are exposed on the dorsal side, the labrum lies considerably caudad on the head, extending across the basal portions of these large jaws. It is rounded on the lateral margins, while on its cephalic border are three prominent forward projecting portions with rather acute terminations. Its dorsal side (Fig. 9), shows numerous long projecting bristles while the ventral side is covered with a rather dense mass of small setæ which project forward.

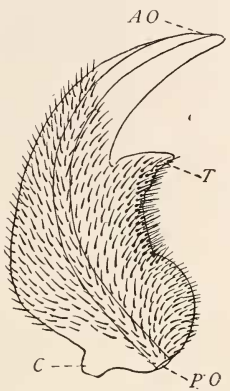

FIG. 10. *Photurus pennsylvanica* larva, left mandible, dorsal view. *AO*, anterior opening of mandibular canal; *C*, condyle; *PO*, posterior opening of mandibular canal; *T*, tooth on inner edge of mandible.

The mandibles (Fig. 10) are very strong. Each has a large curved, anterior tapering tooth and they meet in a median line slightly anterior of the head. On the inner median margin of each mandible is a secondary tooth (*T*). At the base is a knob-like condyle (*C*) by which the mandible articulates with the head. Both mandibles are covered for their entire extent with setæ of varying length, except at the distal end, and around the condyle. About the base is a dense brush of short setæ which project for-

ward. Between this area and the secondary tooth there are larger and stiffer setæ. Those covering the remainder of the surface are rather short and dense. Extending from the base to near its tip is a tubular canal, through which digestive juices

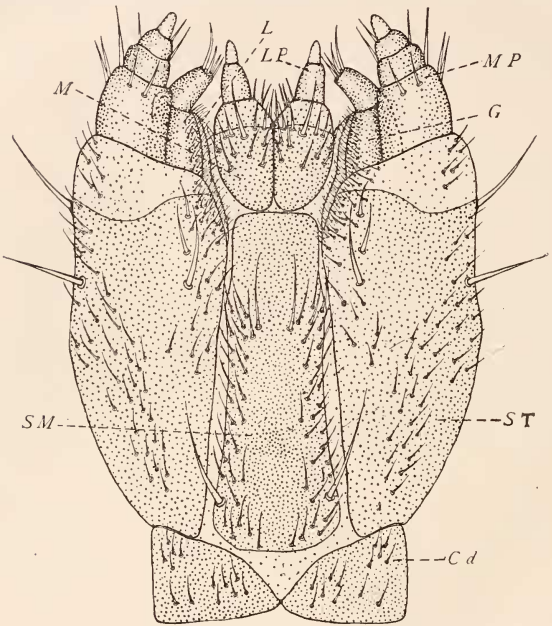

FIG. 11. *Photurus pennsylvanica* larva, labium, maxillæ and lacinia, ventral view. *LP*, labial palpus of labium; *M*, mentum of labium; *SM*, submentum of labium; *MP*, maxillary palpus; *ST*, stipes of maxilla; *Cd*, cardo of maxilla; *L* lacnia; *G*, galea.

pass, while the larva is feeding. It does not open at the tip but slightly caudad on the outer margin.

The maxillæ, labium and lacinia lie on the ventral side of the head, and in these larvæ they are fused into a flat fleshy plate (Fig. 11). When examined on its ventral side, the maxilla has at its caudal portion a small triangular plate, the cardo (*Cd*), which bears several short setæ. Anterior to it is the large elon-

gated stipes (*St*), which also bears several long bristles and many shorter setæ. Anterior of the stipes on the external side is a stout four-segmented palpus, the maxillary palpus (*MP*), bearing several forward projecting setæ. At the side of the maxillary palpus, internally, is the two-segmented galea (*G*) of the maxilla, which resembles very much in appearance a two-segmented palpus. Beside the galea, internally and also extending a short distance along the stipes, is the rather dense chitinized flattened lacinia (*L*). Both the galea and lacinia bear many setæ, and along the inner margin of the lacinia is a row of rather stiff bristles. The tip of the galea ends in short setæ, which probably function as specialized sense organs.

On the ventral side of the labium, the submentum (*SM*) appears much elongated and it lies in the central region of the mouth-parts. It bears numerous short setæ and a few long bristles. The mentum (*M*) is in the form of a thickened bi-lobed structure, from which project anteriorly the two-segmented labial palpi (*LP*). Both structures bear a considerable number of anteriorly projecting setæ and bristles. On the underside, the sclerites of the maxillæ, labium and lacinia are indistinct, though in this region there are numerous small anteriorly projecting setæ.

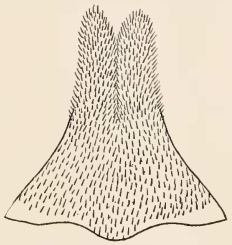

FIG. 12. *Photurus pennsylvanica* larva, hypopharynx, dorsal view.

The hypopharynx (Fig. 12) is triangular in shape with the anterior portion bi-lobed. It is entirely covered with a dense mass of anteriorly projecting setæ, except along its basal portion. The setæ of the anterior half are much denser and longer, and many of them are branched.

From the previous description of the mouth-parts, it is evident that there are numerous setæ projecting forward inside of the mouth region. These setæ, according to Haddon (1915) and Vogel (1915), function as a strainer in preventing all except liquid food from entering the mouth.

In the pharynx region there are several heavily chitinized plates to which numerous muscles are attached, and which,

according to these same authors, function as a suction pump in drawing the liquid food into the mouth. Vogel also described how the mid-intestinal secretions are forced forward, by means of heavy oblique and circular pro-ventricular muscles, into the mouth and out through the mandibular canals.

Though the intestinal juices were not observed passing through the canals of the mandibles, a rather dark-colored liquid was seen suspended from the ends of the long curved teeth and on the bodies of snails and earthworms in the region where the larvæ were feeding. It, therefore, seems very probable that a certain liquid, which, since the larvæ have no salivary glands, must come from the region of the mid-intestine, is exuded through the canals of their mandibles and out through the mouth, and that this liquid functions in paralyzing and digesting the tissues of their prey.

The larvæ were observed, however, to take into their mouths portions of food of considerable size. The fact that they can take up mouthfuls of earth and masticate it in the construction of their pupal-cells is evidence that the larvæ are able to take into their mouths small masses of food before it is completely digested. Yet there can be little doubt but that the greater part of the food is digested outside of the body and taken in through the mouth, in the liquid state. Whether the mandibles function in the intake of food was not determined, but the greater part of it was apparently taken in through the mouth. The portions of undigested food that were taken into the mouth, were no doubt largely digested here before passing on into the intestine, as the larvæ masticated these masses for a considerable time before they disappeared.

The larval light-organs are fully developed at birth, so the larva is luminous from the time that it hatches until it finally enters the pupal state. As stated before, the light is emitted from two elliptical areas on the ventral side of the eighth abdominal segment. The larval light-organs do not emit light in flashes, as the organs of many adults do, but on the other hand, the glow is nearly uniform. While the larvæ were active, the light was found to glow continuously. During the dormant periods, as during the day, but especially during hibernation,

the glow becomes very faint and it frequently is not perceptible even while holding the larvæ ventral side up in a dark room. By moving the insects about so as to agitate them the lights usually become visible. It seems probable that the brilliancy of the glow is in direct proportion to the activity of the larvæ.

The larvæ which were kept in confinement at the insectary were found to go underneath stones, or enter cracks in the soil, late in October, in preparation for hibernation. Some constructed about themselves earthen chambers, while others occupied natural depressions in these protected places. In no instance were they found lying on their dorsal side, such as is characteristic of the pupæ.

During the warm nights of April the larvæ leave their winter quarters and go about in search of food. At this season their little lights can again be seen as they wander about in their natural habitats at night.

Since this species of insect lives as a larva at the base of grass in moist loamy soil, and since it does not enter the ground, or seek other natural means of concealment in which to pass the

FIG. 13. *Photurus pennsylvanica* partially constructed pupal chamber.

pupal period, as many members of the Coleoptera, as well as some Lampyrids do, it constructs a small earthen chamber in which to pass this period of transformation.

A suitable spot on the surface of the ground, usually at the base of moss or grass is chosen, and at once the larva begins building a lattice work of soft earth over itself, in the shape of a small dome (Fig. 13), by which means it conceals itself, in about a day. In the construction of this cell the larva removes earth from underneath itself by means of its mandibles. This it masticates and mixes in its mouth for a period of about half a minute. It then extends its head to the lattice work of the

dome and regurgitates the moist earth in the form of a short ribbon-like mass, which it applies to the walls of the chamber. By the frequent repetition of this process, the lattice-like framework finally entirely covers the larva (Fig. 14). Even after it forms a complete dome, the larva can be seen for several hours between the meshes, before it is entirely concealed. By repeatedly removing the earth from the bottom of the chamber

FIG. 14. *Photurus pennsylvanica* pupal chamber completed, lateral view.

and adding it to the inside of the dome-like wall, the chamber is deepened, and its covering is strengthened and made thicker.

The completed chamber is in the form of an elliptical depression in the ground, about one half of an inch in length and about seven sixteenths of an inch in width. Even after the larva conceals itself it continues to add to the walls of the cell until they are from one eighth of an inch, to as much as one half of an inch in thickness.

The time spent in building the pupal-cell is about two days, though larvæ sometimes continue to excavate for three or even four days, making a firmer and thicker covering for their cells.

That the intestinal secretions of the larva are used for moistening the earth, which is used in constructing the cell, there can be little doubt, yet it evidently has no special adhesive content, for the pupal-cells are easily broken, and they seem to offer no more resistance than ordinary earth which has dried, after having been mixed with water. This liquid seems to serve simply as a fluid in which to mix the earth and make it plastic.

From the examination of several of these completed pupal-cells, it seems evident that the method of construction is such as to allow a small amount of air for respiration to pass in and out between their meshes. Some of the domes of the completed

cells, when held against the light, allowed small rays to pass through, giving evidence of their slight porous nature. The pupal-cell, however, makes a sufficiently well-constructed chamber to protect the pupa from drying or other injury. The reason that the larva usually seeks a damp locality previous to pupation is probably for the purpose of choosing a place where excessive drought will not be liable to affect it during transformation.

By the time the pupal-cell is constructed the larva becomes very sluggish, its body becomes distended and in from one to three days the cuticula splits down the anterior half of the back, and the pupa gradually comes forth. From this time,

FIG. 15. *Photurus pennsylvanica* pupal chamber completed, internal view with pupa in position.

throughout the entire pupal stage, it lies on its dorsal side within its pupal-cell, and is largely supported by the long lateral setæ, which project from each of the thoracic and abdominal tergites (Fig. 15).

The straightened out pupa measures about twelve mm. and in the arcuate position ten mm. The body is somewhat depressed, with the appendages and wing-pads rather long, and with the lateral tergites drawn out at considerable length. At the end of each of these appendages is a mass of coarse bristles. The color of the pupa is yellowish white. It is quite active and can move about considerably within its pupal-chamber.

Throughout the entire pupal period the light-organs, that were functional in the larva, can be distinctly seen to emit light,

although they do not shine with a bright luminescence unless the pupa moves, or is disturbed (Fig. 16).

The head, thorax, and even the abdomen of the pupa, as well as the newly emerged adult, have been described as luminous (Williams, 1916). It must be admitted that the entire insect appears faintly luminous at these periods, but the cause for it

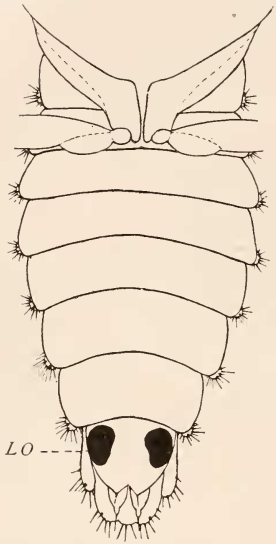

FIG. 16.

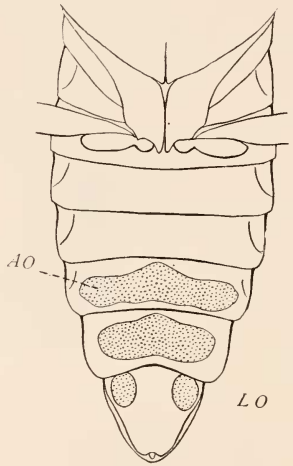

FIG. 17.

FIG. 16. *Photurus pennsylvanica* pupa, ventral view of abdomen. *LO*, larval light-organ.

FIG. 17. Same as Fig. 2, except taken one day after emergence when larval light-organs (*LO*) were still visible. *AO*, adult light-organ.

seems to be due more to the light of the abdominal light-organs shining through the non-pigmented coverings of the insect's body, than to the luminosity of the fat or other internal structures. A freshly molted larva appears much the same as the two stages referred to above.

The date of pupation for this species, at Ithaca, New York, ranges from May 20 to June 15, depending largely on the season.

The extent of the pupal period was found to vary from sixteen to eighteen days under outdoor conditions.

From the fifth of June to about the first of July the pupæ may be found transforming to adults within their pupal-cells. On the first or second night, after transformation, the adult ruptures the pupal-cell and comes forth as a mature insect.

The larval light-organs which are functional during the pupal stage continue to glow until the end of the second day of adult life, when they become fainter and fainter and cease to function.

One species that was reared did not show evidence of the adult organ until after emergence, and then only in the sixth abdominal segment, although the organ in segment seven began to glow a few hours later.

Since the adult light-organs are functional at the time of emergence and since the larval light-organs function for a period of about two days of adult life, there is a brief period during which both organs are luminous (Fig. 17).

Pyropyga fenestralis Mels.

This beetle is elongate, oval and slender. It is entirely black or blackish except for the large pinkish subtriangular space on each side of the black central disc of the prothorax. The head is completely covered by the prothorax. The eyes are small in both sexes. The antennæ are eleven-segmented and slender. The elytra are costate. The sexes are similar except that the female is considerably larger than the male, and her abdomen which is usually distended extends beyond the elytra. The length varies from 6.5 to 10 mm.

LeConte reports these insects from Pennsylvania, Lake Superior Region, Colorado and California. Blatchley found them plentiful in Indiana.

The adults of these fireflies differ from those of the species previously referred to in this paper, in that they are active only during the daytime and not at night. This change in habit can probably be accounted for by the absence of light-organs in the adults. With this one exception, their general habits are similar to those of the other species studied. They are never found in dry localities, being chiefly found in low meadows along streams or marshy areas.

The period of emergence is more prolonged than is characteristic of most species, varying from June 15 to August 10.

During the day these insects can usually be found clinging to grass and weeds by the side of streams. The males are active fliers but the females were not taken in flight, yet it is possible that they fly, for they are sometimes found at a considerable distance from their natural habitat.

The adults were never observed feeding. If they feed at all it is probably very sparingly, for specimens were kept in the laboratory without food from the time of emergence through the period of oviposition.

Copulation was observed to take place from two to ten days after emergence, with frequent repetitions. In the field the copulating pairs were always found about a foot from the ground on a blade of grass or some similar object. The female, early in the season, is usually distended with eggs in varying stages of maturity.

Egg laying starts about four to five days after emergence, and continues for a period of two to three weeks. The females of this species also lay their eggs on the ground at the base of vegetation in damp ground. In every case observed, the eggs were deposited singly.

The egg is small, spherical, whitish in color, measuring about .65 mm. in diameter. It is without surface markings and when first deposited it is covered with an adhesive substance. These eggs, while they are in no sense luminous, give off a slight luminescence when first laid. Under normal conditions they hatch in from nineteen to twenty-one days into little whitish, elongated larvæ.

The larvæ, when first hatched, resemble very closely in appearance those of *Photinus scintillans*, in that they are whitish with dark eyes and brownish mandibles. At this stage they measure about 2.3 mm. in length. On becoming pigmented, however, they appeared dark gray in color.

The mature larva is elongate, narrow, varying from 12 to 14 mm. in length. The blackish head is small, being about half as wide as the prothorax. The body is widest in the region of the thorax and tapers posteriorly. The tergites are dull blackish

in color, while the pleural regions are distinctly pinkish. On the ventro-lateral sternite of the eighth abdominal segment are two luminous areas, the larval light-organs.

Similar to the adults of this species the larvæ are active during the day, though as a rule they are more active at night, when they can be found wandering about on the ground at the edge of streams apparently in search of food. Frequently, however, while searching for them during the day they were found concealed under stones and in the ground to a depth of from one to two inches. On several occasions numbers of them were found assembled together, where they were feeding on a captured snail or earthworm. They were found most abundant at Ithaca, N. Y., on the gravel at the edge of Cascadilla Creek a short distance below the new fish hatchery.

Since these larvæ were active during the day-time, and as they readily took food, it seemed advisable to study more in detail their food habits.

Newport (1857), Meinert (1886), Fabre (1913), Haddon (1915) and Vogel (1915) each studied the food habits of *Lampyris noctiluca*. Newport evidently did not observe closely the mandibles, for he did not mention their hollow nature, which was observed by the other four workers. Newport maintained that the bite of the larva definitely injured the snail upon which it was feeding, while Fabre took a different view, maintaining that the larva injected a substance into its host in the nature of an anæsthetic which paralyzed it, thus making it possible for the larva to feed without being disturbed by the efforts of the snail in trying to escape.

So far as my observations go, I am inclined to believe that the larva does inject a definite substance which serves to paralyze and finally to kill its host. On one occasion a rather small earthworm, about three inches long, was placed with six larvæ. In about two minutes one of the larvæ, as it moved about, feeling its way with its maxillary palpi and antennæ, came in contact with the worm. It touched it several times with these structures, which undoubtedly were supplied with sense organs, and then pierced the worm with its mandibles. The earthworm quickly moved and was evidently slightly injured, but it soon

became quiet. The larva soon released and bit the worm again in the same region. This time the worm moved much less. The process was repeated several times, and each time the worm was less disturbed, until at the sixth or seventh bite the earthworm was not aware of the larva's presence. At about this time another firefly larva bit the worm about an inch away from where the first one was feeding. This part of the earthworm was sensitive, and the worm, though much less active, responded much the same as before. About two minutes later a third larva bit the worm in a still different region, with the result that the worm moved a little but much less than for the other two larvæ. Ten minutes from the time that the first larva bit the worm it apparently was perfectly paralyzed, and so far as could be determined it was dead. Several slugs and snails were observed in the process of being killed by these larvæ. As the reaction of these snails is similar to that of the earthworm, it is sufficient to state that at first the snail appeared to be slightly injured, for in every instance it contracted. In each case, a few minutes after the larva began feeding, the snail was evidently paralyzed for it no longer moved. One of the largest specimens of earthworms obtainable (about seven inches long) was placed in a jar containing moist filter paper with twelve larvæ. Although the worm was left with the larvæ for six days, and though they were given no other food there was no evidence of any effort being made to eat it.

While feeding on its prey, the larva keeps its jaws actively moving back and forth, apparently ejecting digestive juices from its mid-intestine by way of the mandibular canal, and with the two inner teeth on the mandibles it tears the worm to pieces and draws small portions into its mouth. At times the larva would almost bury itself inside the body of its prey, apparently preferring the softer internal tissues to those of the exterior. From an examination of the mouth and intestinal contents of larvæ, which were killed while they were feeding, and from careful observation of their feeding habits, it seems evident that a certain amount of digestive juices are exuded through the mandibular canals into the host, when it is first attacked, which serve to paralyze it. It is also probable that a certain amount of the

digestive juice is constantly being exuded through the mouth as well as by these canals, while the larva is feeding, which serves to break down and partially digest the tissues of the host. Further, it was evident that small portions of undigested flesh, as well as food that was nearly digested, was taken into the mouth, where it was bathed in the digestive juices and worked back and forth by means of the two mandibular teeth, and that liquid food together with very small portions of partially digested food passed into the crop and intestinal region where digestion was completed. As far as could be determined, the mandibular canals did not serve for the intake of foods, as in the Chrysopidæ, but they appeared to function, as far as digestion is concerned, simply as canals for exuding digestive fluids into the host.

At frequent intervals while feeding, certain of the larvæ were observed to extend the caudal filaments, twist the body around, and apply them to the portion of food that was being eaten. It appeared as if the larva was placing some glandular secretion upon the food, or possibly helping to push it into its mouth.

Other experiments were performed to determine whether or not these larvæ limited their food to snails and earthworms. On successive days cutworm larvæ (*Peridroma margaritosa* Haworth, *Paragrotis tessellata* Harris), potato-bettle larvæ (*Leptinotarsa decemlineata* Say), squash-bug nymphs (*Anasa tristis* DeGeer) and wireworms (*Agriotes mancus* Say) were placed in the pots with these firefly larvæ. They readily ate all of the cutworm larvæ, but in no instance were any of the other insects eaten.

From the above experiments it seems evident that these firefly larvæ feed chiefly on snails, cutworms and small earthworms. The other insects that were offered them as food were chosen because they are sometimes found on, or near the ground, and it was desired to see how wide a range of food they would eat.

Although the adults have no light-organs, the larvae have well developed light-organs which resemble very closely, in appearance, those of the other species studied. It, however, appears to be somewhat smaller and emits a less distinct light.

Larvæ were not reared from the egg to the adult, so the length of their life-cycle cannot be given with certainty. Yet, since half-

grown larvæ were found during July and August in association with the mature ones, it seems very probable that the larvæ live for two years before transforming to adults.

Pupation takes place from about June 10 to August 1. The larvæ do not build an elaborate pupal-cell, as the larva of *Photurus pennsylvanica* does, but on the other hand, they crawl back away from the edge of the water, three to ten feet, where they go underneath stones, and there excavate little cells in which the pupal period is spent. The mature larva shortens up slightly and assumes an arcuate position. The cuticula splits down the middle of the dorsal thoracic region and gradually liberates the pupa.

The pupa, except for the yellowish white head, appendages and tip of the abdomen, is of a delicate roseate color. The pleural regions, however, are decidedly pinkish. The abdominal and thoracic tergites are drawn out ventro-laterally into rather acute projections. At the end of each is a mass of setæ. The straightened out pupa measures 8 mm., and in an arcuate position, 6.5 mm.

The pupal period is rather brief, extending for only seven or eight days.

The larval light-organs function throughout the pupal period, but as the time for emergence approaches, the glow usually becomes very faint. In a few specimens the light was observed in the adults for a brief period after emergence.

Purpose of Luminosity.

There can be little doubt but that the chief function of light-emission in insects is to assist in securing the mating of the sexes. It is evident that this has come about as a secondary character when one considers the varying degrees to which the light-organs are developed among Lamyprids. It was suggested by Blair (1915) that possibly the light may be an indication of impalatability. In the case of the adults of *Photinus scintillans*, this does not seem probable, as one frequently finds the females of *Photurus pennsylvanica* and numerous species of spiders feeding upon them. Many adult fireflies when captured emit a pale yellow fluid from between the last coxal joints and from the

pygidium, which it seems may be impalatable to many of their enemies. In the case of luminous larvæ there seems to be little possible use for light-organs, unless it is to warn any possible enemies not to eat them. There are many species of insects outside of the family Lampyridæ that resemble very closely in appearance certain species of fireflies. If the explanation of this mimicry is that of protection, it would seem that the theory of impalatability must have some basis. The exact purpose for the presence of light-organs in larvæ is still indefinitely understood.

Economic Importance.

Practically no work has been done on the possible economic value of these insects, and though the data here given are little more than suggestive, every evidence seems to indicate that these insects are of considerable economic importance. The adults are of little value, as most of them probably eat comparatively little, but the larvæ are voracious little creatures which live on and in the ground, and feed on snails, earthworms, cutworm larvæ, and, in fact, on larvæ of many injurious insects. Most of the soft-bodied animals living on the ground are injurious (unless it is the earthworms), and as the food of firefly larvæ is probably limited to these small animals, they necessarily do much economic good in killing them. The slugs and cutworm larvæ are among our worst economic pests, and it seems evident that they furnish a large part of the food of these larvæ. Since most of the fireflies live two years as larvæ, the number of larvæ that are feeding on the ground during any season is approximately twice that of the adult fireflies. Anyone who has been out during a June or July evening knows that the fireflies are one of our most abundant insects, which, together with the voracious habits of these larvæ leads to the belief that they are of much more economic importance than has been attributed to them heretofore.

Summary.

1. The fireflies studied are luminous both in the larval and adult states, except *Pyropyga fenestralis*, which is luminous only during larval life.

2. In the luminous species the light-organ of the male is

better developed and more brilliant than that of the female. In *Photurus pennsylvanica*, however, the light-organ in the female is nearly as large and as brilliant as that of the male, but in the other luminous species the organ of the female is limited to a small area on the sixth abdominal segment and it emits a rather faint light.

3. The light-organs of the adults undoubtedly function chiefly in bringing the sexes together. The nature of the flash differs for each species, so that members of the same species can readily recognize the flash of the opposite sex. The males and females of certain species, at times, respond to the light of a small flash-light, indicating that this is not always true.

4. In all these luminous species, except *Photurus pennsylvanica*, the female orientates her abdomen so that the light emission is in the direction of the male.

5. In all the species studied the larval light-organ degenerates and, in the luminous species, separate light-organs are developed, which function during adult life.

6. In the case of *Photinus consanguineus*, synchronous flashing was observed in which a few leaders, by flashing, acted as a stimulus to the discharge of the flashes by the others, thus bringing about the flashing in unison of the whole group.

7. The adult fireflies were not observed feeding, except the female of *Photurus pennsylvanica*. She was found to be very voracious, feeding chiefly on the adults of smaller fireflies, but at times she was found to be cannibalistic.

8. The larvæ of all species were found to be predaceous, feeding on snails, earthworms and numerous species of insect larvæ, especially cutworms. They are at times quite voracious, and it seems evident that they are of considerable economic importance.

9. By means of their hollow mandibles, the larvæ eject a portion of the mid-intestinal juices into its host, thereby paralyzing it, and later digesting it so that when the food is taken into the body it is in a digested or nearly digested condition.

10. The larval life, at least, in most of our native fireflies, extends over a period of two years, during which time the larvæ live on or near the surface of the ground.

11. All species that were studied hibernate as larvæ underneath stones, a short distance under the ground or near the surface, often in specially constructed chambers.

12. Pupation takes place in moist earth under stones, or in specially constructed pupal cells at the surface of the ground. The pupal cell of *Photurus pennsylvanica* is made of short, ribbon-like pieces of earth, which the larva masticates and constructs into a lattice-like dome.

13. The pupæ retain the larval light-organs which function throughout the pupal period. This period was found to be from seven to eighteen days according to the species.

14. The adults live for a period of two to four weeks, during which time they deposit their eggs on the ground about the roots of grass and moss.

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